Modeling Sedimentation on the Continental Margin

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Award #. N0014-95-1-0202

LONG TERM GOAL

Our long-term goal is to construct mathematical descriptions of the processes that form sedimentary deposits at all spatial scales on continental margins, and to conduct numerical experiments that will allow us to predict the fabric of the resulting sedimentary deposits.

OBJECTIVES

A first objective is to investigate the pattern (fabric) of seabed stratification on continental margins at small time and space scales (1 cm-50 cm depth into the sea bed; 1 hr-3 yrs sedimentary record). To this end, we are testing the hypothesis that on muddy shelves such as the northern California shelf, Holocene event stratigraphy consists of the deposits of high concentration storm regimes associated with river floods, alternating with deposits of low concentration storm regimes. In order to conduct the test, we are developing several "deterministic" algorithms (EVENT, RESUSPEND, and TRANSPORT), that are driven directly by STRATAFORM and NOAA current meter records.

At inter-mediate spatial scales (1-20 m depth into the sea bed; 1- 1,000 yrs), we are testing a second hypothesis. The hypothesis states that the hypothesis that facies assemblages are stacked on, or are capped by erosional bounding surfaces (source diastems,) in patterns reflecting fluid power gradients in the parent disposal system; and that these patterns are responses to progressive sorting and stratal condensation mechanisms. At intermediate time and space scales, Hood and Storm current records are not available. In order to conduct the test, we have embedded EVENT in an algorithm (FACIES) that is driven by probability density functions describing flood and storm current frequencies.

At large time and space scales (1-1,000 m depth into the sea bed; 12.5 million yrs) we are testing a third hypothesis. The hypothesis states that that depositional sequences can be explained in terms of shifts in the equilibrium configuration of shelf surface in response to changes in sea level, the rate and character of sediment input, and the hydrodynamic climate. In order to conduct the test, we have developed a combined stratigraphic model (morphodynamic-geodynamic model; (SEQUENCE), are modifying it to deal with multiple grain sizes (MULTISEQUENCE), and will embed the intermediate scale model (FACIES) within it.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE **Modeling Sedimentation on the Continental Margin**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Old Dominion University,Department of Oceanography,Norfolk,VA,23908**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

APPROACH

We propose to test the “:flood” bed hypothesis by driving event bed simulation directly from times series of bottom velocity and concentration measurements, and by comparing these hindcasts with observations. At ODU, we have developed a simplified 2-D event bed model (EVENT). The hypothesis will be tested by simulation of the 1995-1997 stratigraphy of the Eel River sector of the Northern California Shelf, as revealed in time series obtained from STRATAFORM tripods. The simulations will be constrained by the box cores collected on the 1997 MELVILLE Cruise and the 1998 WECOMA and CORAL SEA cruises). These samples will be subject to grain size analysis and Xradlography.

Initial studies will take place at the 50, 60, and 70 m stations of the S, 0 and K lines and on 60M and 60Q. Eventually, the full data M9707 data set will be subjected to correlation length scale analysis for grain size and stratal thickness.

We propose to test the Facies assemblage hypothesis by linking deterministic algorithms for boundary layer sediment suspension, redeposition and strata formation (EVENT) with a probabilistic algorithm for stratal succession. (FACIES; Zhang et al., 1997, in press). We propose to incorporate in this model the effects of variable sea level change, sediment input and hydraulic climate. We will compare results by statistical means with observations of box cores, piston cores and seismic records. We will coordinate with NRL in the development of the Seabed classification system (high resolution profiling system) and with NRL in laboratory intercalibmtion of grain size methods.

We propose to test the equilibrium margin hypothesis by combining the morphodynamical model for continental margin evolution developed by URS Greiner--Woodward Clyde (1995) with &Eke Steckler's (1993) geodynamical model, leading to a combined stratigraphic model (SEQUENCE). Initial results are exciting, and we nave several papers in press (Carey et al., in press, in revision). The WCI group has developed a preliminary expansion of the algorithm in which multiple grain sizes are transported and deposited (MULTISEQUENCE).

WORK COMPLETED

During FY98, we (Chris Reed, URS-Greiner--Woodward Clyde) have developed a 2-D version of TRANSPORT that evaluates cross-shelf sediment transport in response to waves, tides and wind-driven currents. We (Shejun Fan, ODU) have developed a modified I-D version of TRANSPORT, in order to explore the behavior of high Concentration regimes (RESUSPEND). We (D. Swift and R. Clayton, ODU) have taken part in the 1997 WECOMA Cruise (Leg 4) and the CORAL SEA cruise, in order to collect constraining data (Box Cores, Piston cores and Bothner cores; and "chirp" seismic records).

RESULTS

During FY 98, Simulations using EVENT and RESUSPEND show that short lived, coasthugging, surface flood plumes, forming over the inner shelf of Northern California during winter storms, leave behind them slowly consolidating, high-concentration, near-bottom suspensions (fluid mud). During the first subsequent storm, bottom shear stress levels on the inner shelf are sufficient to break the lutocline and resuspend flood deposits, hence inner shelf flood beds are rapidly removed and transported seaward by offshore bottom flows during subsequent events. In this manner, high-energy winter rc-sedimentation events, occurring within days or weeks of the flood, rework mud-rich material. The resulting resuspension continues to maintain high concentrations, in which high rates of flocculation occur, leading to poorly sorted, muddy, post-flood storm beds on the central shelf. These sediments were brought to the depositional site by marine currents, and are “flood” beds only in that having formed in the immediate post-flood period, the storm events that deposited them were high concentration events.

Later spring and summer resuspension episodes involved higher levels of critical bed-shear stress, and a reduced supply of fine sediment. They create less dense concentrations that are not high enough to “freeze” the turbid bottom flow, and not high enough to form large floes with high shear resistance, so the settling process leads to better sorting, resulting in thin, sandy “storm” beds that are the product of low-concentration regimes. The resulting storm beds (Fig. 1) are thin and sand rich, partly as a consequence of *in situ* winnowing, and partly as a consequence of advection of sand from the further inshore. In years characterized by major floods, These thin beds may appear as an upward- coarsening, bloturbated cap on the top of a thick “flood” bed.

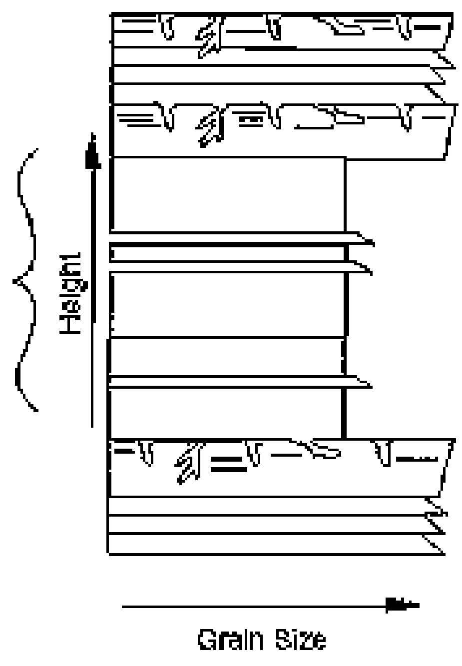

***Fig. I Diagram illustrating relationship between depositional regime and bed architecture on Northern California Shelf*.**

IMPACT AND APPLICATIONS

EVENT will predict the geotechm'cal and acoustic properties of first meter of the sea floor. FACIES will predict the geotechm'cal and acoustic properties of first 10 meters of the sea floor. SEQUENCE will predict seafloor structure at depths up to several kilometers, for foundation studies and petroleum exploration.

TRANSITIONS

We are, in structural terms, the most “downstream” component of STRATAFORM in the sense that we use the results of other STRATAFORM groups as constraining data. The process is linear however, but has feedbacks; our modeling results have lead to changes in the approach of our observationist Colleagues (Mike Field's seismic work, USGS, Menlo Park, and Neal Dnscoll's seismic work, WHOI The larger oceanographic community outside of STRATAFORM are also consumers of our products. We are presently exchanging code with Peter Cowell, University of Sidney, Australia, and other members of the PACE group (Predicting Aggregate Coastal Evolution) funded by the European Economic Community.

RELATED PROJECTS

We are calibrating the models against dynamical data sets collected by STRATFORM investigators (Cacchione, Sternberg, and Wright). We are validating the models by comparison with the sea floor observations of other STRATAFORM investigators (Drake, Wheatcroft, Borgeld, Bentley, Traykovski, and Nittrouer) We arc cooperating closely with ongoing STRATAFORM modeling efforts by Syvitski and students (IAAR), and by Steckler at LDEO. We plan also to collaborate with Wiberg (UVA).

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